

## FINAL REPORT FOR NAG 5-2741

## SS 433: Total Coverage of 162-Day Precession Phase in Four Years

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May 22, 1997

This proposal was submitted by N. Kawai, and I am the US co-I. The project resulted in ASCA observations in April 1996 of the unique Galactic binary source SS 433. This source emits two jets of material which travel in opposite directions at  $0.26c$  (i.e., a quarter the speed of light). These jets precess with a period of 162 days, tracing out a cone with a half-angle of  $19^\circ$ . Observations at different phases of this 162 day precession period therefore provide views at different angles to the jet. SS 433 has been observed a number of times over the life of the ASCA mission, revealing an extremely rich spectrum: lines of Mg, S, Ar, Si, Ni, and Fe are observed both from the stationary frame of the binary system and from red- and blue-shifted gas in the jets.

The observations prior to AO-4 covered a number of precession phases, leaving a gap at phase 0.8. In addition, ASCA and previous observations of SS 433 did not observe the spectrum above  $\sim 10$  keV, and consequently the continuum underlying the spectral lines was poorly constrained. Therefore *RXTE* observations were scheduled for April 1997 to extend the observed spectrum to higher energies; these observations were planned to sample the X-ray lightcurve during the 13.08 day binary period, concentrating on the eclipse of the compact object which emits the jets. We proposed and were awarded ASCA observations simultaneous with the *RXTE* observations; the purpose of the ASCA observations was to provide greater spectral resolution at the low end of the spectrum observed by *RXTE*, and to complete the phase coverage of SS 433.

As a result of scheduling difficulties early in the mission, the *RXTE* observations were confined to a much shorter time range than originally planned, April 18-21 1997. Optical observations of SS 433 were performed at a number of observatories. The ASCA observations occurred from April 18 13:10 (UT) to April 21 13:20 (UT) for a total effective exposure of 120 ks.

The continuum X-ray light curve shows that the ASCA observations started shortly before the ingress into the X-ray partial eclipse, and ended approximately at the time of the egress. Light curves were also obtained for the prominent Fe emission lines in the blue-shifted frame (approaching jet), red-shifted frame (receding jet), and the stationary frame (fluorescent line from the ambient matter). Through the eclipse mapping technique using the light curves, the parameters of the jet emission model were constrained, showing that the kinetic power in the jet exceeds  $10^{40}$  erg s $^{-1}$ . If the energy source is gravitational accretion, as is commonly believed, the derived kinetic power implies extremely super-critical accretion even for a black hole with  $10M_\odot$ . These results will be described more fully in a major presentation of all the ASCA observations of SS 433 which will constitute T. Kotani's thesis.

The *RXTE* observations have been reduced partially. The analysis has been slow

because many software and instrumental issues remain to be addressed this early in the *RXTE* mission. SS 433 was detected by HEXTE, the high energy detector, to an energy of  $\sim 55$  keV; during the binary eclipse the X-ray flux drops by a factor of  $\sim 3$ , indicating that most of the X-ray emission originates within  $\sim 10^{12}$  cm of the binary. The analysis of the observations by the PCA, *RXTE*'s low energy detector, is more preliminary, in part because some of the data files have not yet been provided. The synthesis of the ASCA and *RXTE* results will be published later.